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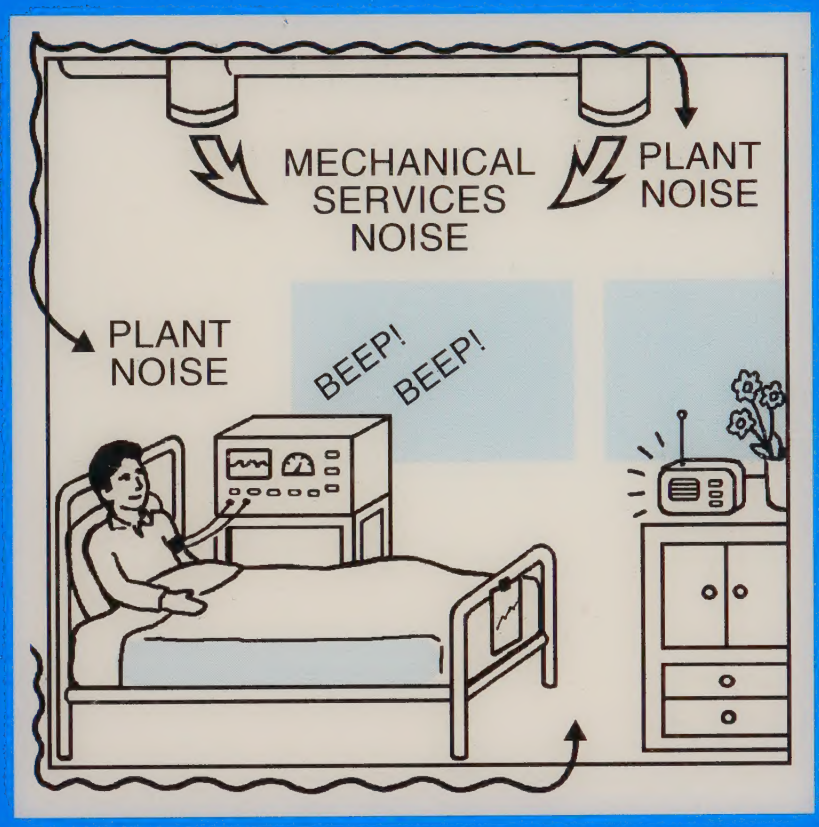
Acoustics

Audiology

Health Technical Memorandum 2045



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Health Technical Memorandum 2045

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The price of this publication has been set to make some contribution to the costs incurred by NHS Estates in its preparation.

About this publication

Health Technical Memorandum (HTM) 2045 – 'Acoustics' is mainly applicable to new sites, but measures have sometimes been given which could also be applied retrospectively to existing buildings. It gives advice and guidance to healthcare management, design engineers, estates managers and operations managers on the legal requirements, design implications, maintenance and routine measures which should be adopted.

HTM 2045 is published as four separate volumes, each addressing a specialist discipline:

- **Management policy** – details overall responsibility of managers of healthcare premises and details their legal obligations to control noise in healthcare premises.

- **Design considerations** – does not set out to give instruction in design work, but highlights the overall requirements and considerations that should be applied to noise control;

- **Validation and verification/ Operational management** – provides information on the commissioning process, routine maintenance and monitoring;

- this volume – **Audiology** – relates specifically to acoustic considerations of audiology suites. The document covers management policy, design considerations, validation and verification and operational management.

The contents of this Health Technical Memorandum in terms of management policy, operational policy and technical guidance are endorsed by:

a. the Welsh Office for the NHS in Wales;

b. the Health and Personal Social Services Management Executive in Northern Ireland;

c. the National Health Service in Scotland Management Executive.

This HTM was written with the advice and assistance of experts in the NHS and industry.

Executive summary

This document describes the acoustic requirements for audiology test facilities.

Part A describes management responsibilities and provides a functional overview, detailing acoustic parameters and noise control requirements.

The appropriate acoustic design criteria in relation to audiology facilities are discussed in Part B. The design criteria given assume that hospital facilities need to measure 0 dB hearing thresholds. General ambient noise from all sources is to be specified in terms of maximum noise rating (NR) values. The requirements of clinical audiometric test rooms, sound field rooms and research areas are discussed.

Noise from mechanical services and vibration levels must be controlled to ensure that the ambient noise levels are not exceeded. The degree of airborne sound insulation provided by a facade or partition will determine not only how much noise from external noises breaks into a building or room but also how much noise caused by activities and conversation within a room breaks out. In order to ensure privacy throughout audiological areas, internal partition performance requirements should be established through the use of the "privacy factor" concept.

The use of the sound reduction index, internal noise transfer, impact sound insulation and reverberation times is explained, and the relevant British Standards for measuring these are identified. Audio systems are required to meet standards of intelligibility: a minimum speech transmission index (STI) of 0.5 is recommended in coverage zones. STI may be estimated and measured using the rapid speech transmission index.

Part C focuses on validation and verification procedures which form part of the commissioning process. The objective of commissioning is to ensure that all relevant acoustic criteria have been met and that all performance standards have been satisfied. The document describes the essential elements of a commissioning brief, including design criteria, the presentation of survey data, and the use of instruments.

Quality inspections and verification of equipment details should be carried out prior to commissioning. Standards of workmanship are crucial in relation to acoustic performance.

Commissioning measurement and survey techniques are outlined. The use of noise rating (NR) curves to evaluate mechanical services and intrusive noise is described. Measurement requirements cover type of sound level meter and microphone positions. Measurement of audio system intelligibility and environment noise is discussed and appropriate methods recommended.

A method for evaluating the vibration performance of mechanical plant and intrusive vibration is described. It indicates the position of vibration transducers, calibration requirements and standards.

Part D concerns operational management and highlights management's statutory responsibilities, including the Noise at Work Regulations (1989), the Health and Safety at Work etc Act 1974, the Control of Pollution Act 1974, the Environmental Protection Act 1990 and the Noise and Statutory Nuisance Act 1993.

It also emphasises the need for clear lines of managerial responsibility and competence in those responsible for compliance with statutory requirements. Management attention is also drawn to the need under certain circumstances to carry out regular monitoring of noise levels, particularly where there is a potential risk to employees or problems with environmental noise emissions. Management is also advised of the need to keep adequate records of such surveys.

Appendix 1 provides a glossary of acoustic terms and Appendix 2 provides critical areas noise level criteria.

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1.0 Introduction

1.1 Acoustics in audiological facilities require careful consideration, because the primary function of the facility makes use of natural acoustics inside the rooms and booths. It is essential that an acoustic specialist is employed for this type of facility.

1.2 Background noise levels must be carefully controlled to meet strict criteria in order to ensure that audiological tests can be carried out properly.

1.3 Noise must be controlled in a number of ways. For example, the interior noise environment must be sufficiently insulated against local external noise sources. This can be done in many ways, including provision of adequate sound insulation in an external wall or careful siting of a facility away from major noise sources.

1.4 This document relates specifically to acoustic considerations of audiology test facilities (which may be enclosed in ENT departments). It replaces any guidance previously given with regard to acoustics in audiological areas.

1.5 This document should be used in conjunction with the other volumes of HTM 2045 – 'Acoustics' when acoustic guidance is required for healthcare premises which include other facilities as well as audiology suites.

1.6 This document contains acoustic requirements for an audiology department, which can also be applied (although generally less stringently) in hearing aid centres and ENT clinics.

Part A: MANAGEMENT RESPONSIBILITIES

2.0 Statutory requirements

Noise at Work Regulations 1989

2.1 The Noise at Work Regulations 1989 (NAW Regs) is an important piece of legislation aimed at protecting the hearing of employees exposed to noise. Employers have a general duty to reduce the risk of hearing damage as far as reasonably practicable within areas under their responsibility.

2.2 Once certain noise level thresholds have been reached, certain measures must be actively sought to reduce noise levels below these thresholds. The thresholds are termed "Action Levels".

2.3 At the First Action Level, employers must provide for a noise assessment of the workplace. Information must be provided to workers on the potential for hearing damage and adequate, properly maintained ear protection must be made available for those who request it. Employers must ensure that all equipment provided under the Regulations is used (with the exception of ear protectors).

2.4 At the Second Action Level the above paragraph applies, along with the requirement to mark ear protection zones and reduce exposure to noise by engineering methods. Ear protection must be worn in all ear protection zones.

2.5 The NAW Regs are most likely to apply to maintenance staff working in noisy plant areas.

The Health and Safety at Work etc Act 1974

2.6 The Health and Safety at Work etc Act 1974 (HSW Act) contains more general duties regarding noise. An example of when action might be needed under the HSW Act would be if the audibility of warning signals and messages is impaired by high background levels.

2.7 In audiometric test facilities, warning sounds in corridors would not be audible within the test rooms.

2.8 See the Firecode documents for guidance on warning signals in audiometric facilities.

The Noise and Statutory Nuisance Act 1993

2.9 The existence of one further act should be known. The Noise and Statutory Nuisance Act 1993 is not directly relevant to healthcare premises but will be to associated activities. It covers nuisances arising from vehicle and building alarms, loudspeakers and other noise in public areas.

Other responsibilities

2.10 The management's general responsibility to patients and staff includes careful consideration of the acoustic environment within which they work and visit. Waiting areas should not be so noisy that patients' hearing thresholds are temporarily reduced before an audiological test. Also, noisy environments are stressful for people with hearing aids.

2.11 Internally, problems can occur if, at one extreme, high noise levels make communication difficult and conditions stressful for staff and patients alike. Conversely, if noise levels are too low, privacy may be compromised and patients may feel isolated. Noise levels within healthcare premises will also depend, for example, on local circumstances; that is, whether the premises are located in a city or the countryside.

2.12 The appropriate acoustic environment for a particular room or building depends largely on the anticipated use of the room. Some rooms which have critical requirements for speech intelligibility, such as operating theatres, require specialised treatment of the walls and ceilings. For example, the reverberation time in such rooms is extremely important, and different surface finishes can help to achieve criteria.

2.13 A site must not be or become a nuisance to the external environment. Often people will look to noise for a reason to complain about an activity if they feel aggrieved by it for any other reason. BS 4142 – 'Method of rating industrial noise affecting mixed residential and industrial areas' is a method which allows the prediction of the likelihood of complaints from site neighbours. Site activities can be legally restricted if noise from the site is not carefully controlled.

2.14 If audiological areas are to be included in premises, special consideration has to be given to some strict and unique requirements. These include exceptionally quiet ambient noise levels and special internal acoustic conditions.

2.15 Noise control by "engineering methods" is the preferred treatment for controlling plant and ventilation-system noise, both internally and externally. These methods include vibration isolation to reduce structure-borne noise and vibration, attenuators for heating and ventilation ductwork, and adequate building envelopes to control noise "break-out" and "break-in".

Operational management

2.16 To comply with the Noise at Work Regulations 1989, an employer must continually take steps to reduce noise levels as far as reasonably practicable. This includes regular monitoring of noise levels in "noisy" environments. Noise at work surveys should normally be carried out at regular intervals; the frequency of these intervals depends on individual circumstances and how "at risk" the workers are. This can be ascertained once the first survey has been done. If exposure levels are close to the prescribed limits, then it may be necessary to monitor closely on a frequent basis.

2.17 Any noise control devices which may be required to reduce levels by "engineering methods" (as required at the Second Action Level in the NAW Regs) are largely passive and require little, if any, performance monitoring. Simple maintenance and cleaning is normally all that would be required.

Designated staff functions

2.18 A person intending to fulfil any of the staff functions specified below should be able to prove that they possess sufficient skills, knowledge and experience to properly perform their designated tasks. This requirement also forms part of some of the regulations described in the above sections.

2.19 Management – management is defined as the owner, occupier, employer, general manager, chief executive or other person who is ultimately accountable for the safe operation of the premises.

2.20 Acoustic specialist – a person appointed or contracted by the general manager to advise on matters concerning acoustics, noise and vibration. Such services are required for audiology test facilities.

2.21 Competent test person – a person appointed or contracted by the general manager to carry out acoustic, noise and vibration tests and surveys. However, this person would normally be the acoustic specialist.

2.22 Maintenance person – a member of the maintenance staff, or a noise control equipment manufacturer or installer employed by the management to carry out maintenance duties on noise control equipment installations. The maintenance of, for example, the attenuators on ventilation ducts would normally be done by the person responsible for maintaining the ventilation system.

2.23 Contractor – the person or organisation responsible for the supply of the noise control equipment, its installation, commissioning and validation as appropriate. This person would not normally be a member of the general manager's staff.

3.0 Functional overview

Terms in use

3.1 Where this document generally refers to "noise", it is normally anticipated that "vibration" will be included in this term. A general explanation of the terms is given below.

Vibration

3.2 Vibration is induced into buildings and other structures when, for example, a machine has rotating parts. The rotating parts may be unstable, by design or otherwise, and vibration can be induced into a structure if not properly controlled. This may be felt by occupants, cause malfunction in sensitive equipment or, in a severe form, cause structural damage by fatigue. It can also be re-radiated as noise.

Noise

3.3 Noise is normally defined as "unwanted sound".

Acoustic parameters

3.4 Most acoustic measurements are given in terms of the decibel (dB). The decibel scale is logarithmic; that is, it can not be manipulated in conventional arithmetic ways. For example, 45 dB + 45 dB equals 48 dB, not 90 dB.

3.5 The human ear does not perceive all frequencies of sound to the same extent. For this reason, a weighting correction is sometimes applied to dB measurements, the most common being the "A-weighting". Subscript "A" or dB(A) is assigned to any parameters when this is the case.

3.6 The background noise level is denoted by L_{90} (or L_{A90} if A-weighted). It is the level in dB exceeded for 90% of the time. Similarly L_2 is the level which is exceeded for 2% of the time.

3.7 L_{eq} is the equivalent continuous sound pressure level and corresponds to the steady sound level over a period of time which would contain the same total sound energy as the noise under consideration for the same period of time.

3.8 Noise rating (NR) criteria are a series of curves used to describe noise. They enable a noise spectrum to be described by a single number and are particularly useful for noise from mechanical services plant, and heating and ventilation systems.

3.9 Reverberation time (RT) is a measure of the time it takes sound in a room to die away after it has been stopped. It is defined as the time in seconds it takes for the sound level to drop by 60 dB. Alternative symbols include T60, RT60 and T_R.

Others

3.10 "Acoustic environment" or "acoustic climate" is a general description of the complete acoustic nature of an area. It could be described using acoustic parameters such as L_{A90}, L_{Aeq}, NR and RT. (See above for basic descriptions of these parameters.)

Noise control requirements

3.11 Noise break-in from the exterior to interior can be controlled by provision of an adequate building envelope, that is, walls, windows or roof. Design requirements depend on individual cases, and acoustic advice needs to be incorporated at the building design stage for the most cost-effective solutions.

3.12 Plant and machinery noise and vibration can be controlled in a variety of ways, again depending on the specific requirements. For example, anti-vibration mounts are used to reduce machinery vibration which could cause structure-borne noise. Attenuators are put into ductwork systems to reduce noise transmitted through such systems.

3.13 To control noise sources may require the rest of a healthcare premises to be investigated. For example, mechanical services plant may well introduce noise to a ductwork system which could be introduced in audiological areas should they be served with the same ventilation system.

4.0 Management action

4.1 The guidance in this HTM should be applied in full to all new installations, and retrospectively where problems exist.

4.2 Noise control will need to be provided:

a. as a requirement for accurate audiological diagnosis;

b. to create a suitable working environment;

c. in order to fulfil a statutory duty.

4.3 The statutory need for noise control is summarised below:

a. the Noise At Work Regulations 1989 require employers to reduce the risk of hearing damage as far as reasonably practicable at all levels. At high noise levels, action must be taken to protect the hearing of workers by appropriate method;

b. the Health and Safety at Work etc Act 1974 requires the person responsible to ensure that audible warning sounds can be heard in all areas and to safeguard people on the premises who are not at work.

4.4 It is a management responsibility to ensure that an appropriate acoustic environment is provided and maintained.

Part B: DESIGN CONSIDERATIONS

5.0 Principles of acoustics

Readers should refer to Chapter 2 of the 'Design considerations' volume of this HTM.

6.0 Specification of acoustic design criteria

6.1 This chapter covers the setting of appropriate acoustic design criteria in relation to audiological facilities. Emphasis has been placed on achievable and practical criteria which are straightforward to use. Consideration has also been given to the extent to which the various criteria lend themselves to commissioning surveys.

Parameters

6.2 The design criteria given assume that hospital audiology facilities need to measure 0 dB hearing thresholds.

6.3 Equivalent continuous sound pressure level (L_{eq}): a method of expressing sound pressure levels measured over a given time period. Can be quoted as frequency-dependent values or an overall A-weighted value, designated L_{Aeq}.

6.4 Noise rating (NR) curves: a system for quantifying frequency-dependent noise levels with a single number. Used for the assessment of both mechanical services and intrusive noise.

6.5 Vibration dose value: an index used to reflect the annoyance caused by whole-body vibration, which takes into account varying amplitude of weighted acceleration and the duration and frequency of intermittent vibration events.

6.6 Weighted apparent sound reduction index (R'_w): used to quantify the airborne sound insulation performance of building elements.

6.7 Weighted standardised impact sound pressure level ($L'_{nT,w}$): used to quantify the impact sound insulation performance of building elements.

6.8 Reverberation time (RT): a measure of the "echoic" nature used to describe the acoustical character of an internal space.

Ambient noise

6.9 General ambient noise criteria from all sources should be specified in terms of a maximum NR value for each area under consideration. For non-critical areas within audiology suites, the values given in Table 1 are appropriate.

6.10 Total ambient sound pressure levels from all sources in an audiometric test room shall not exceed certain values to avoid masking of the test tones, and are based on figures given in ISO 8253 Part 1.

6.11 The total ambient sound pressure levels from all sources in the audiometric test room where the lowest hearing threshold level to be measured is 0 dB (0 dB HL) should not exceed the values given in Appendix 2 for more than 2% of the time, that is, an L_2 in each one-third octave band. This includes noise from the mechanical services.

Table 1 General ambient noise level criteria for non-critical areas

Location	Recommended NR level for ambient noise
Fitting rooms	25
Hearing aid test	25
Environmental room	25
Observation rooms	25
Patient interview	30
Hearing aid repair	35
Consultation rooms/offices	35
Room in which audiometric small booths are housed	35
Audiology clinic waiting room	40
Staff office/rest room	45

6.12 Clinical audiometric tests need to measure 0 dB hearing threshold and therefore the ambient noise level, measured as an L_2 in the test facility, must meet the values given in Appendix 2.

6.13 Sound field rooms, such as those used to assess children's hearing, may have replaced criterion of +10 dB HL or 10 dB higher than each one-third octave band value given in Appendix 2.

6.14 Rooms for research purposes generally testing otologically normal people should have a stricter criterion of –10 dB HL, that is, the total ambient noise must be 10 dB lower than each one-third octave band value in Appendix 2.

6.15 Bearing in mind that the use of such facilities is extremely specialised, detailed discussions with the end-users of the facility should take place before setting criteria for individual rooms.

6.16 A vestibular function test room should be quiet but does not need to meet the above stringent criteria. The ambient noise level from all sources in each octave band between 31.5 Hz and 8 kHz inclusive should not exceed NR 25. These levels should be 1-minute sampled L_{eq}s.

6.17 Ambient noise can come from many sources. Some of these are:

a. mechanical services noise;

b. intrusive noise from external environment:
   (i) road traffic noise;
   (ii) aircraft noise;
   (iii) railway noise;
   (iv) industrial noise (possibly on healthcare premises);

c. internal noise from other areas of the clinic/healthcare premises;

d. vibration causing structure-borne noise to be re-radiated.

6.18 Ambient noise in audiometric facilities must be controlled in order to avoid masking of the test tones.

Mechanical services

6.19 Noise from mechanical services must be controlled to ensure that the ambient noise levels are not exceeded. Note that for specialist areas the noise levels are given in dB L_2, as opposed to dB L_{eq} for other areas.

6.20 Care must be taken to ensure a comfortable working and test environment in audiometric facilities due to the significant level of thermal insulation inherent in the audiometric booth design.

6.21 Mechanical ventilation and cooling will generally be required for audiometric facilities.

6.22 Any services penetrations must be designed to ensure they do not undermine the construction which they penetrate.

Vibration

6.23 Guidance on satisfactory magnitude of building vibration with respect to human response is given in BS 6472.

6.24 Continuous vibration should be assessed in terms of the RMS value of the frequency-weighted acceleration in the floors of occupied areas. Limits may be set in terms of the direction of vibration; either foot-to-head vibration (z-axis) or back-to-chest/side-to-side (x- or y-axis). Generally, the former corresponds to vertical and the latter horizontal vibration. However, if occupants are lying down, as in the case of hospital wards, this correspondence is reversed, z-axis corresponding to horizontal and x- or y-axis to vertical vibration. Limits are recommended as multiples of a base value:

Base value of frequency-weighted acceleration:

z-axis	0.005 m/s^2 RMS
x,y-axis	0.0035 m/s^2 RMS

A multiplying factor for different types of accommodation corresponding to a low probability of adverse comment is:

Location	Multiplying factor
Vestibular function test facilities	1
General consulting	4
Rooms/offices	4

6.25 Intermittent vibration should be assessed in terms of the vibration dose value (VDV) measured in units of $m/s^{1.75}$ in the floors of audiological test areas. VDVs corresponding to a low probability of adverse comment for different areas within the audiology clinic are as follows:

	z-axis	x,y-axis
Offices/general laboratories	0.4	0.28
Areas with vibration-sensitive equipment	0.1–0.2	0.07–0.14

However, in audiological and vestibular function test facilities, it is not appropriate to make allowance for intermittent events. The maximum

frequency-weighted acceleration should therefore be within the limits set in 6.29 for continuous vibration.

6.26 In audiometric test areas the vibration levels must be measured prior to design/construction of the facilities. This will allow the vibration isolation requirements for audiometric facilities to be established.

6.27 Vibration levels must be controlled so that re-radiated noise levels in an audiometric room do not contribute to the overall noise level in the room. Generally, the re-radiated noise level due to vibration should be 20 dB lower than the total noise level allowable in that room.

Airborne sound insulation

External facades

6.28 The degree of airborne sound insulation provided by a facade (or facade element) dictates how much noise from external sources breaks into the building. Hence the facade performance requirement is dependent upon the relevant intrusive noise criterion, and the facade performance itself need not necessarily be specified. The intrusive noise criterion should be derived bearing in mind noise from other sources, such as mechanical services, so that the combined level does not exceed the relevant criterion given in this document.

6.29 Under certain circumstances, it may be deemed necessary to specify the actual performance requirement for a facade. Even when the criteria are in terms of intrusive noise limits, the facade performance requirement will have to be identified at some point during the design process. The procedure for calculating facade requirements is laid out below:

a. spectral noise data for external sources should be obtained from surveys, predictive calculations, or a combination of both;

b. the appropriate intrusive noise criterion (or criteria) should be used in conjunction with the external noise data to calculate the facade performance requirement in terms of weighted apparent sound reduction index as defined in BS 5821 Part 3.

External partitions

6.30 Where audiometric test facilities are situated on an external wall, the facade requirements must be calculated at all one-third octave band frequencies between 31.5 Hz and 8 kHz inclusive, to control break-in to audiometric test facilities.

6.31 It is usual to avoid external windows in audiometric test facilities since glazing usually does not provide sufficient sound insulation.

Internal partitions

6.32 The airborne sound insulation performance requirements of internal partitions are closely linked to intrusive noise criteria. However, another very important factor is "privacy", that is, the extent to which conversation and activities in one area are audible in an adjacent area.

6.33 In order to ensure adequate privacy throughout a development, internal partition performance requirements should be established through the use of the "privacy factor" concept.

6.34 Privacy factor is based on knowledge of:

a. the subjective privacy requirement for the areas under consideration;

b. the mechanical services noise levels in the areas under consideration.

In all cases, the more stringent privacy requirements and services noise levels should be utilised.

6.35 Privacy factor (PF) is defined as:

$PF = R'_w + B$

where:

R'_w is the site-tested weighted apparent sound reduction index;

B is the mechanical services noise criterion in terms of NR.

6.36 Table 2 identifies the privacy factor requirements for various subjective situations.

Table 2 Privacy factor categories

Privacy factor (PF)	Resulting privacy assuming normal speech
<70	Clearly audible and intelligible
70–75	Audible but not intrusive
75–80	Audible but not intelligible
>80	Inaudible

Table 3 lists recommended privacy factors for various locations within healthcare premises. The PF for each area is for any part of the building envelope enclosing that room, regardless of what is adjacent to it. Once the PF has been used to calculate the required R'_w values for each room, the higher of the two R'_w should be used where adjacent rooms have different requirements. For example, if a consultation room (PF80, R'_w 50) is next to a cafeteria (PF70, R'_w 35), the dividing partition construction must achieve R'_w 50.

6.37 Examples of use of privacy factor are:

- from Table 3, the required PF for private offices is PF 80. The ambient noise criterion (B) for offices is NR 35 (see Table 1). Due to the way the criteria have been set in this document, 5 dB must then be deducted from the ambient noise criterion to give an estimate of the constant mechanical services noise level. Therefore the required weighted apparent sound reduction index (R'_w) of all partitions enclosing the office is given by:

$R'_w = PF - (B - 5)$

where

B is the ambient noise criterion from Table 1

$= 80 - (35 - 5)$

$= 50$ dB

Table 3 Recommended privacy factors assuming normal speech effort

Location	Recommended privacy factor (PF)
Audiology: fitting room, observation room	80
Maternity, nursery, A&E	80*
Operating theatre, single-bed ward, multi-bed ward, private office, meeting and consultation rooms, lecture theatre	80
Laboratory, staff room, general office	75
Waiting room, corridor, washroom, toilet, kitchen, recreation room, cafeteria	70

* These rooms are identified as areas which are likely to have an increased voice effort as a noise source, that is, shouts or screams. 20 dB should therefore be added to the PF of any adjacent room to account for this. Paragraph 6.37b gives details of corrections to the PF which may be required in certain areas if an increased voice effort (raised voices, shouts, screams) is anticipated.

Hence the required site-tested weighted apparent sound reduction index (R'_w) of all the office partitions is R'_w 50 dB;

- when voices are raised, the sound level in the source room can be increased by up to 20 dB and therefore, to achieve the same level of privacy, the following correction factors should be added to the PF of the adjacent (receiver) room:

Voice effort	Voice effort correction factor (C)
Raised	5
Shout	10
Scream	20

Hence for a different voice effort, say a patient screaming (in a maternity ward for example), the required weighted apparent sound reduction index (R'_w) of the dividing partition could be increased by 20 dB. Therefore, where the private office in the example above is located next to a maternity ward, the R'_w of the office wall becomes:

$$R'_w = PF - (B - 5) + C$$
$$= 80 - (35 - 5) + 20$$
$$= 70 \text{ dB}$$

6.38 Similar procedures should be adopted for other construction elements which may affect internal noise transfer, for example suspended floors and ceilings. The performance requirements here would be in terms of weighted suspended ceiling normalised level difference ($D_{n,c,w}$) and weighted floor normalised level difference ($D_{n,f,w}$). For design calculation purposes these parameters would be treated in exactly the same way as R'_w.

6.39 Example of use of privacy factor for different voice effort: The privacy factor between two fitting rooms should be 80. The background noise level in fitting rooms is NR 25. Assuming that the patients often speak with a raised voice, the required weighted apparent sound reduction index (R'_w) of the dividing partition is given by:

$$R'_w = PF - B + C$$
$$= 80 - 25 + 5$$
$$= 60 \text{ dB}$$

Hence the required R'_w of a partition between fitting rooms where raised voices often occur is 60 dB.

6.40 The noise sources used within audiometric clinics must be considered when calculating the required sound reduction indices between test facilities. For example, a warble-tone generator creates significant noise levels and is usually the controlling factor for floor/ceiling/partition construction requirements.

6.41 Similar procedures should be adopted for other construction elements which may affect internal noise transfer, for example suspended floors and ceilings. The performance requirements here would be in terms of weighted suspended ceiling normalised level difference ($D_{n,c,w}$) and weighted floor normalised level difference ($D_{n,f,w}$). For design calculation purposes these parameters would be treated in exactly the same way as R'_w.

When calculating the overall R'_w of a room, it should be noted that the average sound insulation of all elements is lower than the insulation value of each individual element, for example, a R'_w40 floor, R'_w40 wall and R'_w40 ceiling would give an overall R'_w. of 35 dB.

Impact sound insulation

6.42 "Impact sound" refers to noise generated in areas due to some form of impact (for example, footsteps) on the surface of the floor in the area above. The first step in setting appropriate design criteria is to identify those areas where this should be a consideration. For guidance, it is recommended that all areas in regular use should be effectively insulated from impact sound.

6.43 Impact sound is assessed using the parameter weighted standardised impact sound pressure level ($L'_{nT,w}$), which is defined in BS 5821 Part 2. Due to the fact that this parameter relates to noise level measurements in a room as opposed to a characteristic of a building element, impact sound criteria are given in terms of a "not-to-be-exceeded" value.

6.44 The impact sound insulation performance of floors between occupied areas should be such that, when tested, the arithmetic mean of all results for $L'_{nT,w}$ does not exceed 61 dB. Furthermore, no individual value should exceed 65 dB.

6.45 For audiometric test facilities, impact noise must be controlled to ensure the **total** noise level in a booth does not exceed the hearing threshold level in dB HL set for that booth. This will generally be higher than the figures given in paragraph 6.44 above.

Reverberation times

6.46 Internal surface finishes should be selected such that the reverberation times at all frequencies between 125 Hz and 4 kHz are within the ranges shown in Table 4. In test rooms and audiology booths the reverberation time in frequencies between 31.5 Hz and 100 Hz shall not exceed the values given in Table 5.

Table 4 Recommended reverberation times

Location	Reverberation time (s)
Test rooms/Audiology booths	0.2–0.25
Waiting rooms	0.6–0.9
Private offices	0.5–0.7
Consultation rooms	0.5–0.7

Table 5 Low frequency reverberation time in audiology booths

	One-third octave band centre frequency (Hz)					
	31.5	40	50	63	80	100
Reverberation time(s)	0.8	0.8	0.5	0.5	0.5	0.3

Audio system intelligibility

6.47 A minimum standard for intelligibility of audio systems may be found in BS 7443. This standard requires that audio systems with an emergency function must achieve a minimum speech transmission index (STI) of 0.5 in all coverage zones.

6.48 It is recommended that **all** audio systems, whether for emergency use or not, should achieve a minimum STI of 0.5 in coverage zones.

6.49 STI may be estimated and measured using the rapid speech transmission index (RASTI) method as defined in IEC 268-16.

7.0 Sources of noise and provision of noise control

7.1 Readers should refer to Chapter 4 of the 'Design considerations' volume of this HTM.

7.2 The above reference details various sources of noise which may be relevant both to general healthcare developments and audiology clinics.

7.3 It is arranged in four sub-sections:

a. planning considerations:
   - exterior noise;
   - interior noise, spacing between adjacent audiology test rooms;

b. constructional techniques:
   - principles of sound insulation;
   - application of sound insulation;
   - principles of sound absorption;
   - applications of sound absorption;

c. noise control of building services plant and machinery:
   - detailing methods of controlling specific sources of noise;
   - sizing of ductwork for low velocity system;

d. vibration control.

7.4 Within this document, design criteria have been set. As long as the noise criteria are met with regard to the audiological test areas, individual developments may be designed in whatever fashion is deemed suitable.

7.5 Commercially available audiology booths may be the preferred option due to the stringent criteria required and the fact that they can be placed within a room housing the control equipment. However, there is nothing wrong with building a room as part of the construction providing it meets the noise criteria.

7.6 Readers should refer to Health Building Note 12, Supplement 3 – 'ENT and audiology clinics' for various suggestions on location design and facilities.

Part C: VALIDATION AND VERIFICATION

8.0 Introduction to commissioning

8.1 The objective of commissioning is to ensure that all relevant acoustic criteria have been met and all appropriate performance standards have been satisfied.

8.2 The commissioning process involves a variety of survey techniques designed to produce results which can then be compared against the relevant design criteria.

8.3 It is vital that those responsible for undertaking commissioning are fully conversant with the appropriate acoustic principles and survey techniques. This normally means that commissioning is performed (or overseen) by those responsible for specification of noise control measures and other acoustical treatments.

8.4 Commissioning results should be carefully collated and used to verify compliance with criteria or otherwise. Furthermore, such results can be of use in determining the degree of success achieved by the various measures. This would normally be of use in future work involving similar situations.

8.5 Due to the nature of noise transfer and propagation, it will not be possible to commence commissioning until all elements of the installation (or construction) are complete. However, this does not prevent indicative measurements and inspections being performed prior to starting detailed commissioning surveys.

Commissioning brief

8.6 Those responsible for commissioning will require a detailed brief. The contents of this brief will depend on what knowledge of the project the commissioning personnel already have. Such a brief would typically include:

a. an introduction describing the nature of the project and the purpose of the commissioning survey;

b. a listing of all appropriate design criteria;

c. a listing of all measurements required in order to demonstrate compliance with the design criteria;

d. a statement as to how commissioning survey data is to be presented.

8.7 Guidelines as to minimum standards for instrumentation should be issued. This should involve instructions on verifying the accuracy of test instruments which should be supported by relevant calibration certificates. Note that very specialised equipment is needed to commission audiology facilities. Standard Type 1 sound level meters will not suffice.

8.8 Where necessary, personnel familiar with the operation of noise-generating equipment should be instructed to run it under normal operating conditions.

8.9 Should design criteria fail to be met in any instance, further investigative measurements and inspections will normally be required in order to identify the source of any problems.

8.10 On demonstrating that all design criteria have been met, a full report should be prepared and included with handover documentation.

9.0 Pre-commissioning checks

9.1 A number of preliminary inspections and tests would normally be required prior to commencement of final commissioning.

Quality inspections

9.2 Standards of workmanship are very important in relation to acoustic performance. This applies equally to builder's-work items such as partitions or suspended ceilings and to proprietary acoustical hardware such as enclosures, attenuators or absorptive wall treatments.

9.3 In particular, the following should be verified:

a. that constructions designed to limit transfer of sound (for example partitions, enclosures) are complete in all respects and have no weaknesses such as gaps around the perimeter;

b. that doors and openable windows have been sealed as specified;

c. that all sealing materials (such as non-setting mastic) have been applied as specified;

d. that all proprietary acoustical items have been installed in accordance with manufacturers' instructions;

e. that all noise-generating equipment is operating "normally".

Verification of equipment details

9.4 All installed noise-generating equipment should be checked to ensure that it is commensurate with the details used to assist with the specification of noise control measures. Where this is not the case, any implications on noise generation should be identified prior to commissioning.

9.5 All acoustical hardware should be inspected to ensure that it complies with the project requirements. In particular, performance parameters should be confirmed and included with the commissioning brief.

10.0 Commissioning measurements

10.1 There are a number of survey techniques covering the variety of design parameters which may be involved in any given project. The survey techniques are outlined in the following sections.

10.2 Depending upon the particulars of a specific project, the commissioning brief should reference the appropriate survey techniques.

10.3 In this document, background noise level criteria have been recommended for various non-critical areas in the audiology clinic such as consultation rooms, waiting areas etc. These background noise level criteria include noise from mechanical services, intrusive noise and structure-borne noise.

10.4 The more stringent criterion for audiological testing facilities uses different parameters. Commissioning of these rooms is dealt with separately to the more general (non-critical) areas.

Background noise in non-critical areas

10.5 The noise rating (NR) system is the adopted method to evaluate general background noise in non-critical areas. Using this method it is possible to quantify frequency-dependent measurements with a single number. Further details on NR can be found in paragraph 2.13 of the 'Design considerations' volume of this HTM.

10.6 Noise level measurements should be carried out with all plant and machinery operating normally and achieving the design conditions of airflow, temperature and humidity. Furthermore, the mechanical services installation should be operating at its normal design setting, although it would be appropriate to carry out further measurements if the system is expected to operate at different settings. Activities which would normally occur in the surroundings should also be present as noise sources.

10.7 Noise level measurements will be required in all non-critical areas for which criteria have been set. The measurements should be performed in unoccupied rooms and it is recognised that intrusive noise may be present in unpredictable quantities. For these non-critical areas, this factor should be made as representative of "normal" envisaged noise as possible, and measurement locations should be established by considering worst-case scenarios.

10.8 Having established those areas in which measurements are required, the exact locations should be identified. In doing this, the following should be taken into consideration:

a. anticipated usage of the area;

b. likely locations of area occupants;

c. locations of proprietary items such as grilles, diffusers or perimeter heating units;

d. size of the area.

For guidance, in small rooms (say, less than 75m^3), it should normally be acceptable to carry out a single measurement. In larger rooms, it may be necessary to establish a grid of measurement locations.

10.9 The measurements should be performed using a sound level meter complying with the requirements of BS 5969. This standard specifies meters having four degrees of precision, designated Types 0, 1, 2 and 3. Under normal circumstances, a Type 2 meter should be acceptable. However, for more critical and/or contractual situations a Type 1 meter would be required. Frequency band filters should comply with the requirements of BS 2475.

10.10 The measuring microphone should be located at a height of approximately 1.5 m above floor level, and should be at least 1 m away from any room surfaces or large objects such as filing cabinets.

10.11 Measurements of L_{eq} (equivalent continuous sound pressure level) should be made in each octave band between 63 Hz and 8 kHz. The sample period may be varied depending upon conditions, but 5 to 15 seconds per octave band should generally be sufficient.

10.12 The octave band results for each location should be analysed to give a single NR value using the method given in paragraph 2.13 of the 'Design considerations' volume of this HTM. Further analysis may be required in order to determine the presence or otherwise of unacceptable tonal components. Depending upon the instrumentation being utilised, it may be possible to establish NR values during the commissioning process. However, it is more usual to do this at a later stage.

10.13 In the event of a measurement result indicating failure to meet a design value, further detailed assessment may be required in order to identify the nature of the problem and appropriate remedial noise control measures.

Background noise in critical areas

10.14 Where noise level criteria for critical areas have been set, the following procedure should be adopted for the commissioning process.

10.15 The occasional "loud" noise cannot be tolerated in critical areas and for this reason, different criteria have been set for areas where audiometric tests will be carried out.

10.16 Noise level measurements should be carried out with all plant and machinery operating normally and achieving the design conditions of airflow, temperature and humidity. Furthermore, the mechanical services installation should be operating at its normal design setting, although it would be appropriate to carry out further measurements if the system is expected to operate at different settings.

10.17 Commissioning measurements of the critical areas are likely to prove difficult because of the specialist low-level equipment which would be required. Advice should be sought from an acoustic consultant with the ability to carry out such measurements. The measurements should be made by the acoustic consultant after discussions with the end-users of the facility on the process adopted to adequately commission individual cases.

10.18 The ambient noise level measurements shall be made in terms of dB L_2 at a time when conditions are representative of those existing when audiometric tests are carried out, that is, during the day, when adjacent areas are occupied by people.

Vibration

Vibration from mechanical plant

10.19 Vibration from mechanical plant is evaluated in terms of frequency-weighted acceleration in the floor. Measurements should be made with all plant and machinery operating normally. Where items of plant are designed to operate at different speeds it would be appropriate to measure vibration over the speed range.

10.20 Vibration measurements should be taken in all areas adjacent to equipment and plant rooms, vertically as well as horizontally. The measurements should be taken in unoccupied rooms in the absence of vibration from sources other than services plant and machinery. It is recognised that vibration from external sources out of the control of those carrying out the measurements may affect the readings. If such intruding vibration is intermittent, it should be possible to measure services vibration in between the intruding events. If it is continuous at all times of day and the total vibration measured exceeds the criterion, specialist advice should be sought on the acceptability of the vibration levels.

10.21 Measurements should be taken as close as practicable to the centre span of the floor. In large rooms, where there are a number of columns (floor spans) within the room, it may be necessary to choose a number of locations.

10.22 Measurements should be carried out using a set of equipment complying with the BS 7482 Parts 1 and 3. The weighting networks used should be Wg (z-axis) and Wd (x,y-axis) as defined in BS 7482 Part 3.

10.23 The vibration transducer, typically an accelerometer, should be clamped or bonded to the floor, either directly or via a solid metal blade to facilitate the measurement of horizontal vibration.

10.24 Direct readings of the frequency-weighted acceleration level should be taken. Although not recommended, it is possible to measure the weighted acceleration level in one-third octave bands from 1 Hz to 80 Hz and calculate the weighted acceleration level using the weighting values given in BS 6472.

10.25 In the event of a measured result failing to meet the relevant criterion, a more detailed assessment, including the measurement of the frequency spectrum of the vibration, may be required to determine possible remedial measures.

10.26 Before and after each set of measurements the calibration of the measurement chain should be checked using a portable calibration exciter.

Intrusive vibration

10.27 Vibration dose value (VDV) is used to assess intermittent and continuous vibration from external sources.

10.28 Intrusive vibration should be measured in the absence of vibration from building services plant and machinery.

10.29 Measurements should be taken in unoccupied rooms in those areas for which criteria were established during the design. It may not be necessary to measure in every such location, but choose sample locations at which to monitor intrusive vibration.

10.30 Transducer location and fixing on the floor should be as for the measurement of services vibration (paragraphs 10.27 and 10.29).

10.31 Measurements should be carried out using a set of equipment complying with BS 7482 Parts 1 and 3. The weighting networks used should be Wg (z-axis) and Wd (x,y-axis) as defined in BS 7482 Part 3.

10.32 Direct readings of the VDV should be taken over a period of time long enough to be representative, taking into account the variability, of the time or times of day. For residential or sleeping accommodation there are different criteria for night-time as opposed to daytime. If vibration is due to a number of discrete events, it may be practicable for a specialist to determine the VDV for a sample of events and calculate the daytime and night-time exposures.

10.33 If a measured result fails to meet the relevant criterion, a more detailed assessment, including the measurement of the frequency spectrum of the vibration, may be required to determine the cause. However, it may not be practicable to reduce the intruding vibration once the building has been constructed.

Airborne sound insulation

10.34 The parameter used for the evaluation of airborne sound insulation is weighted apparent sound reduction index (R'_w).

10.35 The method of measuring airborne sound insulation is described in BS 2750 Parts 4 and 5.

10.36 Those building elements for which airborne sound insulation criteria have been established should be tested in accordance with the relevant part of BS 2750 in order to determine the apparent sound reduction index (R') in each one-third octave band between 100 Hz and 3150 Hz. In brief, the standard covers:

a. scope of application;

b. definitions of relevant acoustical parameters;

c. requirements for instrumentation;

d. test arrangement;

e. test procedure and evaluation of results;

f. expression of results.

10.37 The frequency-dependent values of apparent sound reduction index (R') should be rated in accordance with BS 5821 Parts 1 and 3.

10.38 Having followed the guidance given in BS 5821, the net result is a single number characterising the frequency-dependent performance. This single

number is the weighted apparent sound reduction index (R'_w), and may be compared directly against the design values for R'_w.

Impact sound insulation

10.39 The parameter used for the evaluation of impact sound insulation is weighted standardised impact sound pressure level ($L'_{nT,w}$).

10.40 The method of measuring impact sound insulation is described in BS 2750 Part 7.

10.41 Those building elements for which impact sound insulation criteria have been established should be tested in accordance with the relevant part of BS 2750 in order to determine the standardised impact sound pressure level (L'_{nT}) in each one-third octave band between 100 Hz and 3150 Hz. In brief, the standard covers:

a. scope of application;

b. definitions of relevant acoustical parameters;

c. requirements for instrumentation;

d. test arrangement;

e. test procedure and evaluation of results;

f. expression of results.

10.42 The frequency-dependent values of standardised impact sound pressure level (L'_{nT}) should be rated in accordance with BS 5821 Part 2.

10.43 Having followed the guidance given in BS 5821, the net result is a single number characterising the frequency-dependent performance. This single number is the weighted standardised impact sound pressure level ($L'_{nT,w}$), and may be compared directly against the design values for $L'_{nT,w}$.

Reverberation times

10.44 Reverberation time (RT) is the parameter most commonly used to quantify the acoustical characteristics of an internal space. It is expressed in seconds.

10.45 RT measurements should be performed in those areas which have been assigned RT design criteria. However, it is often unnecessary to assess every such area. For example, if there are a number of identical offices, it would normally be acceptable to assess the RTs in only one of the offices.

10.46 Reference should be made to BS 5363. Whilst this standard is specific to auditoria, the underlying principles of measurement remain the same whatever the application.

10.47 The resultant measured RTs should be qualified where necessary to account for the following:

a. absorption of furnishings;

b. likely extent of occupation;

c. future changes in layout or surface finishes.

Audio system intelligibility

10.48 The parameter used for the assessment of audio system intelligibility (that is, "clarity") is speech transmission index (STI).

10.49 Speech intelligibility should be evaluated in all areas served by the audio system.

10.50 There exist a number of methods for the measurement of STI. However, the easiest to use is termed rapid speech transmission index (RASTI) and was developed by Bruel and Kjaer. Reference should be made to BS 6840 Part 16. Whilst this standard is specific to auditoria, the underlying principles relating to sound systems remain the same whatever the application.

10.51 Other methods of assessment may be used provided that all interested parties agree beforehand.

11.0 Handover procedure

Design information

11.1 The following information regarding the acoustic elements of a project should be made available:

a. calculations covering noise emissions from plant and machinery along with details of related noise control measures;

b. details of building elements and proprietary materials intended for the control of noise transfer;

c. audio system details including a listing of all areas provided with audio coverage;

d. a clear statement of all acoustical design criteria:

   (i) NR levels for areas served by the building services installation;

   (ii) NR levels for areas where intrusive noise is a consideration;

   (iii) sound insulation requirements in terms of weighted apparent sound reduction index (R'_w);

   (iv) reverberation times;

   (v) speech transmission indices for areas served by an audio system.

Commissioning results

11.2 The following measurement results should be presented:

a. total noise in audiology test facilities (in terms of dB L_2 for each one-third octave and between 31.5 Hz and 8 kHz inclusive);

b. mechanical services noise levels (in terms of NR);

c. intrusive noise levels (in terms of NR);

d. sound insulation ratings (in terms of R'_w);

e. reverberation times (in seconds);

f. speech intelligibility ratings (in terms of STI);

g. environmental noise levels (in terms of the appropriate parameter);

h. comparison of all commissioning results with design criteria, statement of acceptability, details of remedial measures and subsequent changes in results.

Part D: OPERATIONAL MANAGEMENT

12.0 Management responsibilities

General

12.1 The primary management responsibilities may be summarised as follows:

a. the requirements of the Noise at Work Regulations 1989 should be satisfied in all respects;

b. the requirements of the Health and Safety at Work etc Act 1974 should be satisfied in all respects;

c. any notices issued under the Control of Pollution Act 1974 should be actioned immediately;

d. any notices issued under the Environmental Protection Act 1990 should be actioned immediately;

e. care should be taken not to give cause for complaint under the Noise and Statutory Nuisance Act 1993;

f. the acoustic environment in and around the healthcare premises should be appropriate to the various activities undergone;

g. careful consideration should be given to the strict and unique requirements of audiological facilities.

12.2 Clear lines of managerial responsibility should be in place so that no doubt exists as to those who are responsible for the various points outlined in paragraph 12.1 above.

12.3 Those responsible for carrying out routine monitoring and/or ensuring compliance with statutory requirements should be competent to do so. This will require knowledge of basic principles and training to an acceptable standard.

Information

12.4 In order that acoustical standards can be monitored and maintained, the following should be provided:

a. details of all design criteria;

b. details of all noise control measures and acoustical treatments (proprietary or otherwise);

c. results of commissioning measurements, presumably in the form of the handover documentation.

12.5 The information held on file should be updated as necessary in order to provide an up-to-date record.

Training

12.6 Those responsible for carrying out noise surveys should be trained in the accurate operation of instrumentation and correct interpretation of results. It is

likely that a competent test person would have to be appointed for more involved situations or where other trained personnel are unavailable.

12.7 Employees exposed to high levels of noise should receive training on risks of damage to hearing and methods of hearing protection.

12.8 Where noise control hardware requires regular maintenance (for example some audiometric booths may require the internal surfaces to be kept clean to maintain their acoustic performance), the personnel involved should be made aware as to what is required in order to ensure that correct performance is maintained.

13.0 Routine monitoring

13.1 Under certain circumstances it will be appropriate to carry out regular monitoring of noise levels.

13.2 Where there are potential problems with background noise, levels at critical locations should be closely monitored.

13.3 Periodic objective checks of the background noise levels in audiology test facilities are recommended.

14.0 Records

Designated staff functions

14.1 A record should be kept of those appointed to carry out the staff functions listed in paragraphs 2.18 to 2.23. The record should clearly state the extent of the postholder's duties and responsibilities and to whom they should report.

14.2 The details of any training given should be clearly recorded.

14.3 Substitute or replacement staff should be designated to cover for sickness, holidays and staff transfers.

Monitoring

14.4 Where appropriate, the results of noise surveys should be kept on record.

Appendix 1 – Glossary

Absorption coefficient
The proportion of sound lost when incident at a surface.

Absorptive attenuator
Attenuator that incorporates glass-fibre and mineral-wool materials, effective over a wide range of frequencies.

Ambient noise
Encompassing sound (at a given place), being usually a composite of sounds from many sources near and far. Should not be confused with "background noise".

Attenuation
Noise reduction.

Attenuator
Noise-reducing device – often colloquially and incorrectly known as a "silencer".

Background noise
Total of interference from all sources in a system used for the production, transmission, detection, measurement or recording of a signal acoustically quantified using L_{90}.

Breakout
The escape of sound from any source-enclosing structure such as ductwork, metal casings and building envelopes.

Broad-band (or random) sounds
Oscillation due to the aggregate of a large number of elementary disturbances randomly occurring in time.

Crosstalk
The transfer of airborne noise from one area to another via secondary air paths such as ventilation ductwork or ceiling voids.

Decibel (dB)
One-tenth of a bel. A bel is the unit of level of a quantity proportional to power when the base of the logarithm is 10. Also, the unit of level of a field quantity when the base of the logarithm is the square root of 10.

dB(A)
Specific measuring scale achieved by a weighting network fitted in a sound level meter. Gives a single-figure rating to a broad-band sound. dB(A) is approximately equivalent to the human ear frequency response.

Dynamic insertion loss (DIL)
A measure of the acoustic performance of an attenuator when handling the rated flow. Not necessarily the same as Static Insertion Loss, because it may include regeneration.

Equivalent continuous sound pressure level (L_{eq})
Logarithm of the ratio of a given root-mean-square sound pressure, during a stated time interval, to the reference sound pressure. Average sound pressure level in decibels is 20 times the logarithm to the base 10 of that ratio. Unless otherwise specified, the reference sound pressure for airborne sound is 20 μPa (20 micropascal).

Excitation frequency
A frequency at which a machine produces vibration. Often the speed of rotation of the machine.

Flanking transmission
Transmission of sound from a source room to an adjacent receiving room but not via the common partition.

Flutter echo
Rapid but nearly even succession of echoes originating from the same sound source. Often occurs in empty rooms. An echo is defined as a sound wave that has been reflected and arrives with such a magnitude and time interval after the direct sound as to be distinguishable as a repetition of it.

Free sound field
Sound field in a homogeneous isotropic medium where boundaries exert a negligible effect on the sound waves.

Frequency (Hz) – sound
The number of sound waves to pass a point in one second.

Frequency (Hz) – vibration
The number of complete vibrations in one second.

Hertz (Hz)
The unit of frequency equivalent to one cycle per second.

Insertion loss
The reduction of noise level by the introduction of a noise control device; established by the substitution method of test.

Insulation (sound)
The property of a material or partition of opposing sound transfer through its thickness.

Inverse square law
The reduction of noise with distance. In terms of decibels, it means a decrease of 6 dB for each doubling of distance from a point source when no reflective surfaces are present.

Isolation (vibration)
The reduction of vibrational force into a structure.

Isolation efficiency
The amount of vibration force absorbed by an isolator and thus prevented from entering the supporting structure, expressed as a percentage of the total force applied to the isolator.

L_{eq}
See "Equivalent continuous sound pressure level"

$L'_{nT,w}$
See "Weighted standardised impact sound pressure level"

L_{90}
See "Background noise"

Masking noise or sound conditioning
Extra noise introduced into an area to reduce the variability of fluctuating noise levels and improve the intelligibility of speech.

Mass law
Heavy materials stop more noise passing through them than light materials. For any airtight material there will be an increase in its "noise-stopping" ability of approximately 6 dB for every doubling of mass per unit area.

Natural frequency
Frequency of free oscillation of a system. For a multiple-degree-of-freedom system, the natural frequencies are the frequencies of the normal mode of oscillation.

Near sound field
Sound field near a sound source where instantaneous sound pressure and particle velocity are substantially out of phase. The inverse square law does not apply in the near sound field.

Noise
1. Erratic or statistically random oscillation.
2. Disagreeable or undesired sound or other disturbance.

Noise criterion (NC) curves
A US set of curves based on the sensitivity of the human ear. They give a single figure for broad-band noise. Used for indoor design criteria. They are similar to NR curves but have different frequency characteristics.

Noise rating (NR) curves
A set of curves based on the sensitivity of the human ear. They are used to give a single-figure rating for a broad band of frequencies. Used for interior design criteria. They are similar to NC curves but have different frequency characteristics.

Noise reduction
Used to define the performance of a noise barrier. Established by measuring the difference in sound pressure levels adjacent to each surface. (See also Sound Reduction Index)

Octave
Unit of logarithmic frequency interval: two sounds, the ratio of whose fundamental frequencies is 2, have a logarithmic frequency interval of 1 octave.

Octave bands
A convenient division of the frequency scale. Identified by their centre frequency, typically 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz.

Periodic sounds
A signal containing a finite number of pure tones which repeats itself at regular intervals.

Pure tone
Sinusoidal acoustic oscillation.

Reactive attenuator
An attenuator in which the noise reduction is brought about typically by changes in cross-section, chambers and baffle volumes, for example a car exhaust silencer.

Regeneration
The noise generated by airflow turbulence. The noise level usually increases with flow speed.

Resonance
State of a system in forced oscillation such that any changes, however small, in the frequency of excitation result in a decrease in a response of the system.

Resonant frequency (Hz)
Frequency at which resonance exists.

Reverberation
The sound that persists in an enclosed space, as a result of repeated reflection or scattering, after the source of the sound has stopped.

Reverberation time
Of an enclosure, for a sound of a given frequency or frequency band. The time that would be required for the sound pressure level in the enclosure to decrease by 60 dB, after the source has been stopped.

Room constant
The sound-absorbing capacity of a room, usually expressed in m^2.

R'_w
See "Weighted apparent sound reduction index"

Sabine's formula
Predicts the reverberation time of a room or enclosure from known room volume and absorption characteristics. Becomes inaccurate when absorption is high.

Silencer
Colloquialism for attenuator.

Solid state (bottoming)
Vibration isolation, that is, when a spring can be compressed no further and the coils are in contact.

Sound insulation
The property of a material or partition to oppose sound transfer through its thickness.

Sound level meter (noise meter)
An instrument for the measurement of sound level, with a standard frequency weighting and standard exponentially-weighted time-averaging.

Sound power
A measure of sound energy in watts. A fixed property of a machine, irrespective of environment.

Sound power level (L_w)
Logarithm of the ratio of a given sound power to the reference sound power. Power level in decibels is ten times the logarithm to the base 10 of the ratio. Unless otherwise specified, the reference sound power is 1pW.

Sound pressure level (L_p)
Logarithm of the ratio of a given sound pressure to the reference sound pressure. Sound pressure level in decibels is 20 times the logarithm to the base 10 of the ratio. Unless otherwise specified, the reference sound pressure is 20 μPa for airborne sound and 1 μPa for a sound in media other than air. Unless otherwise specified, the sound pressures are understood to be expressed in root-mean-square values.

Sound reduction index (SRI)
Of a partition, for a specified frequency band. Difference in decibels between the average sound pressure levels in the reverberant source and receiving rooms, plus ten times the logarithm to the base 10 of the ratio of the area of the common partition to the total sound absorption in the receiving room.

Sound spectrum
Representation of the magnitudes (and sometimes of the phases) of the components of a complex sound as a function of frequency.

Speech transmission index (STI)
A specialised design and measurement parameter used for the quantification of audio systems. A high value STI indicates a high degree of speech intelligibility.

Standing wave
Periodic wave having a fixed distribution in space that is the result of interference of progressive waves of the same frequency and kind. Such waves are characterised by the existence of nodes or partial nodes and antinodes that are fixed in space.

Static deflection
The distance that vibration isolators compress when loaded.

STI
See "Speech transmission index"

Third-octave bands
A small division of the frequency scale, three to each octave. Enables more accurate noise analysis.

Transmissibility
The amount of vibratory force that is transferred to the structure through an isolator, expressed as a percentage of the total force applied.

Turbulent flow
A confused state of airflow that may cause noise to be generated inside, for example, a ductwork system.

Vibration dose value (VDV)
A parameter used to reflect the disturbance and/or annoyance caused by variable vibration.

Vibration isolation
Any of several means of reducing the transfer of vibrational force from the mounted equipment to the supporting structure, or vice versa.

Wavelength
The distance between two like points on a wave shape, for example distance from crest to crest.

Weighted apparent sound reduction index (R'_w)
A single-number index which characterises the frequency-dependent airborne sound insulation performance of building elements.

Weighted standardised impact sound pressure level ($L'_{nT,w}$)

A single-number index which characterises the frequency-dependent impact sound insulation performance of building elements.

Appendix 2 – Critical areas noise level criteria

Maximum permissible ambient sound pressure levels (0 dBHL)

One-third-octave band centre frequency (Hz) Test tone frequency range	Maximum permissible sound pressure levels Maximum permissible sound pressure levels	
	125 Hz to 8000 Hz	250 Hz to 8000 Hz
31.5	55	63
40	47	56
50	41	49
63	35	44
80	30	39
100	25	35
125	20	28
160	17	21
200	15	15
250	13	13
315	11	11
400	9	9
500	8	8
630	8	8
800	7	7
1000	7	7
1250	7	7
1600	8	8
2000	8	8
2500	6	6
3150	4	4
4000	2	2
5000	4	4
6300	9	9
8000	15	15

Note: This table should be used in conjunction with ISO 8253: Part 1: 1989: 'Audiometric test methods. Basic pure tone air and bone conduction threshold audiometry'.

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BS 5969: see BS EN 60651: 1991

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Part 2: 1991 Guide to the acquisition of data pertinent to land use

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